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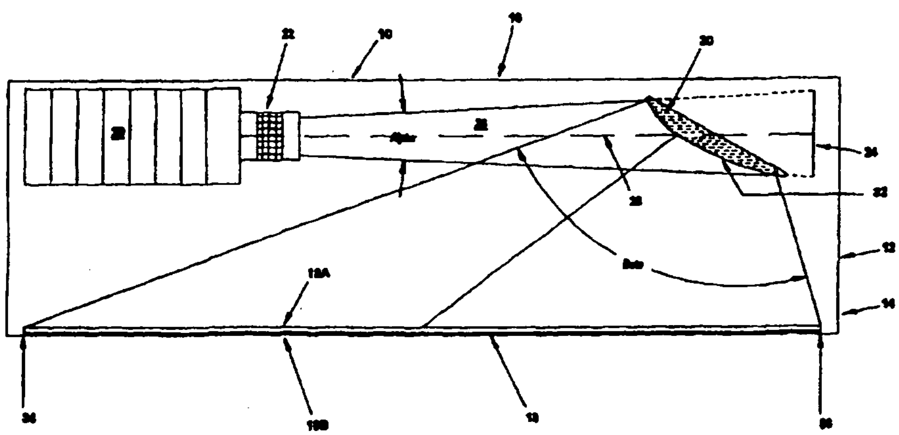

(57) Abstract

The present invention provides an image projecting apparatus (10), particularly a rear screen projecting apparatus, comprising a projecting lensing means (20) for projecting an image of an illuminated object, a screen (18), and reflecting means (30) for reflecting light from the projecting lensing means onto the screen; wherein the reflecting means is positioned off-centre with respect to the screen and asymmetric diverging lensing means (30) are provided for magnifying further the image reflected by the reflecting means onto the screen, the lensing power of the diverging lensing means varying across the area thereof, such that for each point on the diverging means, the combined focal length of the projecting lensing means and diverging lensing means is adjusted according to the length of the optical path between the projecting lensing means and the screen via that point, thereby to reduce optical distortion of the image on the screen. In some embodiments, said diverging lensing means may comprise a toroidal aspheric mirror or a complex aspheric mirror.

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IMAGE PROJECTING APPARATUS

The present invention relates to an image projecting apparatus, particularly the rear screen projector.

In its simplest form, a conventional rear screen projector comprises a translucent screen and a projecting lensing means for projecting an image of an illuminated object onto the screen. Typically the screen will comprise a composite construction consisting of a Fresnel lens and a lenticular lens screen. The projecting lensing means is positioned to one side of the screen, whilst the image is viewed from the opposite side. In order to avoid distortion of the image, the projecting lensing means is positioned and oriented such that the optical axis of the beam emitted by the projecting lensing means is disposed along a line which passes perpendicularly through the screen. The projecting lensing means may comprise a cathode ray tube (CRT), flat panel LCD or a conventional photographic transparency projector. Usually, the projecting lensing means will incorporate a source for illumination, and means for changing the object to be displayed. The principal disadvantage of this kind of rear screen projector is that the projecting lensing means has to be positioned

at a substantial distance from the screen in order to obtain satisfactory magnification of the image. This makes such rear screen projectors very large and cumbersome if a screen of reasonable dimensions is required.

Attempts have been made previously to reduce the overall dimensions of rear screen projectors without sacrificing screen size. US-A-5274406, for example, discloses a rear screen projector in which the light emitted by the projecting lensing means is reflected onto the screen by a mirror. The use of the mirror enables the apparatus to be accommodated within a reduced volume without diminishing the optical path length between the lensing projecting means and the screen. The angle subtended by the mirror and screen is less than 45°, and the mirror is therefore shaped, so as to reduce trapezoidal distortion of the image. The mirror of the apparatus disclosed by US-A-5274406 is positioned centrally with respect to the screen, and does not serve to magnify the image.

According to Japanese laid-open patent application no. 62-31838, the separation of the mirror and screen in an arrangement similar to that disclosed by US-A-5274406 may be reduced by adopting a convex mirror for magnifying

the image reflected by the mirror. According to JP62-31838 however, the mirror must subtend an angle of 45° with the screen.

It is an object of the present invention to provide an improved image projecting apparatus. In particular, it is an object of the invention to provide a image projecting apparatus which can be made more compact as compared with the apparatus known from the prior art, without sacrificing screen size or image quality.

It is a further object of the invention to provide an image projecting apparatus, particularly a rear screen projector, which can be accommodated within a housing in which the screen occupies substantially the whole of one face of the housing, and the apparatus can be accommodated within an area which is coterminous with the screen.

Another object of the invention is to provide a novel lensing mirror which can be used in the manufacture of a compact image projecting apparatus.

In one aspect of the present invention therefore there is provided an image projecting apparatus, particularly a rear screen projecting apparatus, comprising a

projecting lensing means for projecting an image of an illuminated object, a screen, and reflecting means for reflecting light from the projecting lensing means onto the screen, wherein the reflecting means is positioned off-centre with respect to the screen, and asymmetric diverging lensing means are provided for magnifying further the image reflected by the reflecting means onto the screen, the lensing power of the diverging lensing means varying across the area thereof, such that for each point on the diverging lensing means, the combined focal length of the projecting lensing means and diverging lensing means is adjusted according to the length of the optical path between the projecting lensing means and the screen via that point, thereby to reduce optical distortion of the image on the screen.

Said diverging lensing means will be positioned at or towards a position at which the image projected by the projecting lensing means is focused, so that the light incident on each point of the diverging lensing means will correspond to a discrete part of the image. In this way, the lensing power of the diverging lensing means at each point can be pre-selected independently of the rest of diverging lensing means to adjust the magnification of the corresponding part of the image, so that the image is projected substantially uniformly onto

the screen.

Preferably, the overall magnifying power of the diverging lensing means will be such that the divergence of the beam projected by the projecting lensing means is increased between two and twelve-fold by the diverging lensing means. Typically, the intrinsic field of view of the beam emerging from the projecting lensing means may be in the range 10° to 30°, and the intrinsic field of view of the beam treated by the diverging lensing means may be in the range 60° to 100°. The width of the diverging lensing means may therefore be about 10 to 40% of the width of the screen, typically about 25% or less. Moreover, the projecting lensing means can be designed to have zero or nearly zero vignetting, thus minimising the variation of illumination across the screen.

Said diverging lensing means and screen may be positioned with respect to one another such that the image on the screen is magnified between two and twenty times, typically ten times, as compared with the size of the image which is incident on the diverging lensing means.

Said screen will usually be a planar Fresnel lens/lenticular lens screen composite and will be oriented obliquely with respect to the reflecting means.

Said screen may be oriented such that a line on the screen, which line is disposed parallel to the projection of the optical axis between the projecting lensing means and the reflecting means onto the screen, subtends an angle of between 0° and 45° to the said optical axis. Said projecting lensing means may be disposed juxtaposed one end of the screen, and the reflecting means may be disposed juxtaposed an opposing end of the screen. The optical path between the projecting lensing means, the reflecting means and the one end of the screen may be greater than the optical path to the opposing end of the screen. The ratio of these two optical paths will usually be in the range 1.0 to 2.0, preferably 1.1 to 1.6.

In a different aspect of the present invention, the image projecting apparatus may further comprise a housing, and the screen may occupy substantially the whole of one face of the housing. Said projecting lensing means, reflecting means and diverging lensing means may be accommodated within the housing within an area which is coterminous with the screen.

In another aspect of the present invention, the reflecting means may comprise a substantially planar mirror, and the diverging lensing means may comprise an

asymmetrical diverging lens positioned adjacent to the planar mirror, typically a concave diversing lens.

In yet another aspect of the present invention however the reflecting means and diverging lensing means may be constituted by an asymmetrical diverging lensing mirror. Said lensing mirror may be symmetrical about a plane which is disposed normally to the screen, which plane contains the optical axis between the projecting lensing means and the mirror. The profile of the reflecting surface of the mirror in section on this plane will be generally convex, with the radius of curvature varying across the surface of the mirror, from one end where light is reflected towards the one end of the screen where the radius of curvature will be lower than at the other end where light is reflected onto the said opposing end of the screen. The reflecting surface of said lensing mirror may have a complex aspheric shape, which may be defined by the following complex polynomial:-

$$z=\frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}}+a_2r^2+a_3r^3+a_4r^4+a_5r^5+a_6r^6+\ldots$$

wherein:- $a_2, a_3, a_4, a_5, \ldots$ are the aspheric coefficients,

K = Conic Constent

$r^2 = x^2 + y^2$,

c = bone curvature of the surface (1/bone radius),

z is the optical axis,

x is an axis normal to the optical axis and parallel to the screen, and

y is an axis normal to the x and z axes.

Alternatively, said asymmetrical diverging lensing mirror may comprise a toroidal aspheric mirror, the reflecting surface of which may be defined by the following formula:-

$$z=\frac{c_x x^2+c_y y^2}{1+\sqrt{1-(1+k_x)\,(c_x x)^2-(1+k_y)\,(c_y y)2}}+a_4x^4+a_6x^6+a_8x^8+a_{10}x^{10}+b_4y^4+b_6y^6+b_8y^8+b_{10}y^{10}$$

wherein:- x,y and z are as defined above,

$a_4, a_6, a_8, a_{10}, b_4, b_6, b_8$ and b_{10} are aspheric coefficients, and c_x, c_y = bone curvatures of the surface along the x and y axes.

It will be appreciated that the convex surface of the lensing mirror may have the effect of defocussing the light reflected towards the screen.

Accordingly, in yet another aspect of the present invention, said diverging lensing means may comprise refocusing means for refocusing the light treated by the diverging lensing means. Said refocusing means may comprise a transparent refractive coating formed on the surface of the diverging lensing mirror or diverging lens, which transparent coating has a refractive index and surface profile which is controlled for refocusing the light treated by the diverging lensing means. The thickness of the coating may be substantially constant across the surface of the diverging lensing means. Alternatively the thickness of the coating may be varied, so as to control the refocusing power of the coating. In particular, the degree of defocussing occasioned by the diverging lensing mirror or diverging lens will vary according to the radius of curvature thereof, and the surface profile of the coating at each point on the diverging lensing means may therefore be pre-selected so that the refocussing power of the coating at that point compensates for the degree of defocussing of the corresponding part of the image.

Said coating may, in some embodiments, be formed as a plurality of contiguous lenticular lenslets provided on the surface of the diverging lensing means. The lensing power of each lenslet may be pre-selected according to

the position of the lenslet on the surface of the diverging lens or mirror. Said lenslets may be of uniform size, such that the density of levels per unit area is substantially constant across the surface of the lensing means. Alternatively the size and density of the lenslets may vary, with smaller lenslets being used in greater concentration at those parts of the lensing mirror or lens where the shape of the latter is most complex.

It may be the case that when lenslets of this kind are used on the surface of a diverging lensing mirror in accordance with the present invention, some light will be incident on one lenslet and will be reflected by the mirror through a neighbouring lenslet. This will lead to some scattering of the light which passes through the marginal portions of the lenslets. To reduce this problem, the thickness of each lenslet at its extremities may be minimized or reduced to zero. Alternatively, excess coating material could be removed from the margins of each lenslet after application of the coating to the mirror by laser etching. Masking means may be provided juxtaposed the boundary of each lenslet for reducing or preventing the transmission of light which passes through more than one lenslet. Said masking means may comprise a non-reflecting mask applied to the mirror surface, or

an optically-absorbing mask applied to the coating surface, juxtaposed the boundary of each lenslet.

Following is a description by way of example only with reference to the accompanying drawings of methods of carrying the present invention into effect.

In the drawings:-

Figure 1 shows a sectional view through a rear screen projector including a diverging lensing mirror in accordance with the present invention.

Figure 2 shows a detail of a plane mirror plus diverging lens which may be incorporated in the projector of Figure 1 in place of the mirror.

Figure 3 is an optical diagram of a different rear screen projector incorporating a diverging lensing mirror according to the present invention.

Figure 4 is a schematic, isometric view of the reflective surface of a diverging lensing mirror according to the invention.

Figure 5 is another optical diagram of the rear screen

projector of Figure 3 which shows how the diverging lensing mirror causes some defocussing of the light incident thereon.

Figure 6 is an optical diagram of another rear screen projector according to the invention, which projector incorporates a mirror having an optical coating thereon.

Figure 7 is an enlarged detail of the mirror and coating of Figure 6.

Figures 8A to 8E show various alternative mirror coatings for incorporation in the projector of Figure 6.

Figures 9A and 9B show further alternative, lenticular mirror coatings for the projector of Figure 6, which coatings comprise a plurality of contiguous lenslets.

Figure 10 shows a sectional view through a mirror having a lenticular thereon coating of the kind shown in Figure 9A or 9B.

Figure 11 is a sectional view through another mirror having a different lenticular coating formed thereon.

Figure 12 shows an optical diagram of the lenticular

mirror coatings of Figures 9A, 9B and 10, which shows how light may be scattered at the boundaries between contiguous lenslets.

Figure 13 shows a sectional view through another lenticular mirror coating which has been treated by laser etching to reduce boundary scattering.

Figure 14A shows a sectional view through yet another mirror having a lenticular coating thereon and a non-reflective mask juxtaposed the boundary between two neighbouring lenslets.

Figure 14B shows a sectional view through yet another mirror having a lenticular coating thereon and an optically-absorbing mask applied to the surface of the coating along the boundary between two contiguous lenslets.

Figure 15 is a sectional view of a projection lens combination suitable for use in a rear screen projector of the invention.

A rear screen projector (10) according to the invention comprises a generally rectilinear housing (12) of rectangular cross-section. Said housing (12) comprises

two opposing short walls (14) and two opposing long walls (16). One of said long walls is cut-out to accommodate a rectangular, translucent screen (18) which occupies substantially the whole area of the one long wall (16). Said screen (18) consists of laminate comprising a Fresnel lens (19A) and a lenticular lens screen (19B). Such composite screens are well known in the art.

Said housing (12) accommodates a projection device (20) which is disposed juxtaposed the other long wall (16) remote from said screen (18) and towards one of the short walls (14).

Said projection device may comprise a CRT, flat panel LCD, DMD, or plasma or FED display device. Alternatively, said projection device (20) may comprise a conventional slide/film projector. Whichever form of projection device is employed, it will comprise a combination of projection lenses (22) such, for example, as the lens combination shown in Figure 11 for magnifying and focusing an image of an object. Said projection lenses (22) have a focal plane (24) which is disposed adjacent to the opposing short wall (14) of the housing (10) as shown in Figure 1. Said projection device (20) generates a divergent beam (26) which extends from the projection lenses (22) towards the focal plane (24) and

has an intrinsic field of view, $\propto$, in the range 10° to 25°, typically 15° to 20°.

Juxtaposed said focal plane (24), the housing (10) accommodates a diverging lensing mirror (30). Said beam (26) is incident on a generally convex surface (32) of the mirror (30), and is thereby reflected towards the screen (18).

Said mirror (30) is symmetrical about a plane which is normal to the screen (18), which plane contains the optical axis (28) of the beam (26). In this plane the mirror (30) has a width less than about 25% of the width of the screen (18). The mirror (30) serves to magnify substantially the image projected by the projecting device (20) such that the beam reflected by the mirror (30) has an intrinsic field of view, β, in the range 60° to 100°, typically about 80° to 85°. It will be appreciated that the optical path taken by light from the projecting device (20) to the mirror and thence to a first end (34) of the screen (18), which first end (34) is juxtaposed the projecting device (20), will be substantially longer than the optical path taken by light from the projecting device (20) to the opposing second end (36) of the screen (18). The convex surface (32) of the mirror (30) is profiled such that the lensing

power of the mirror (30) at each point at its surface (32) is determined according to the optical path length between the projecting device (20) and screen (18) via that point. The radius of curvature of each point on the surface (32) of the mirror is thus pre-selected, so that the image is magnified substantially uniformally onto the screen (18). The radius of curvature of the surface (32) is thus greater at the end of the mirror juxtaposed the projecting device (20) as compared with the radius of curvature at the opposing end of the mirror (30) where the light incident thereon has the shortest optical path.

In an alternative embodiment as shown in Figure 2, the diverging lensing mirror (30) may be replaced by a planar mirror (129) positioned with juxtaposition with the focal plane (24), which mirror (129) serves merely to reflect the light emerging from the projecting device (20) towards the screen (18), and a generally concave, asymmetric diverging lens (130) which serves to magnify the image reflected by said mirror (129). The lensing power of the diverging lens (130) varies across the surface (132) thereof in the same way as the diverging lensing mirror (30) in the previous embodiment, so as to ensure substantially uniform magnification of the projected image on the screen (18), thereby to reduce or substantially eliminate optical distortion of the image.

In the two embodiments described above, the screen (18) is oriented such obliquely with respect to the mirror (30;129) that a line on the screen (18), which line is parallel to a projection of the optical axis (28) onto the screen, is substantially parallel to the said optical axis (28).

In a different embodiment as shown in Figure 3, this line subtends an angle of about 30^0 to the optical axis (28). It will be appreciated by a person skilled in the art however that this angle may in fact vary between 0^0 and as much as, say, 60^0 without departing from the principles of this invention. Naturally, as the orientation of the screen (18) is varied with respect to the mirror (30) or mirror plus lens combination (129,130), the surface profile of the mirror (30) or lens (130) will vary to compensate for the concomitant changes in the optical path lengths between the projecting device (20) and screen (18).

An example of a suitable asymmetric diverging lensing mirror (30) for use in the embodiments of Figure 1 or Figure 3 is illustrated in Figure 4. This diverging lensing mirror (30) has a toroidal aspherical mirrored surface (32) which may be defined by the following formula:-

$$z=\frac{c_x x^2+c_y y^2}{1+\sqrt{1-(1+k_x)(c_x x)^2-(1+k_y)(c_y y)2}}+a_4x^4+a_5x^6+a_8x^8+a_{10}x^{10}+b_4y^4+b_6y^6+b_8y^6+b_{10}y^{10}$$

wherein:- $a_4, a_6, a_8, a_{10}, b_4, b_6, b_8$ and b_{10} are aspheric coefficients.

z is the optical axis,

x is the axis normal to the optical axis and parallel to the screen,

y is the axis normal to the x and z axes.

c_x and c_y are the bone curvature of the surface along the x and y axes respectively.

In the present example, said toroidal aspheric mirror (30) has the following coordinates:-

X = 0		X = ± 23.16		X = ± 40.45		X = ± 57.97	
Y	Z	Y	Z	Y	Z	Y	Z
96.89	150.18	96.89	150.17	97.10	148.38	97.41	145.76
87.46	147.66	87.47	147.60	87.68	145.65	87.98	142.83
77.98	145.12	78.00	144.99	78.20	142.86	78.48	139.82
68.45	142.55	68.47	142.30	68.66	139.99	68.93	136.69
58.86	139.93	58.88	139.51	69.06	136.99	59.31	133.44
49.21	137.22	49.24	136.69	49.40	133.83	49.63	130.02
39.60	134.38	39.54	133.47	39.68	130.48	39.87	126.39
29.73	131.36	29.77	130.12	29.89	126.88	30.04	122.53
19.90	128.04	19.94	126.44	20.02	122.98	20.12	118.40
9.99	124.32	10.02	122.38	10.06	118.73	10.11	113.97
0.00	120.00	0.00	117.87	0.00	114.10	0.00	109.28
-10.10	114.87	-10.13	112.90	-10.17	109.12	-10.23	104.29
-20.35	108.68	-20.38	107.54	-20.47	103.86	-20.58	99.16
-30.79	101.24	-30.77	101.98	-30.89	98.51	-31.05	94.02
-41.47	92.42	-41.28	96.53	-41.43	93.30	-41.63	89.06
-52.44	82.24	-51.89	91.58	-52.07	88.55	-52.30	84.50
-63.73	70.84	-62.56	87.60	-62.76	84.67	-63.04	80.63
-76.38	58.35	-73.80	79.98	-73.87	76.70	-74.24	72.27
-87.41	44.94	-84.94	71.24	-85.28	67.63	-86.74	62.73
-99.84	30.73	-96.52	62.16	-96.93	58.26	-97.49	52.94
-112.69	15.82	-108.34	52.78	-108.83	47.60	-109.50	42.90

Alternatively, a complex aspheric mirror may be used which may be defined by the following polynomial:-

$$z=\frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}}+a_2r^2+a_3r^3+a_4r^4+a_5r^5+a_6r^6+\ldots$$

wherein:- x, y and z are as defined above,

$r^2 = x^2 + y^2$,

$a_2, a_3, a_4, a_5, \ldots$ are the aspheric coefficients

k = conic constent,

c = bone curvature of the surface (1/bone radius).

Naturally, for any specified embodiment, the actual surface configuration of the toroidal or aspheric mirror may be mapped using computer modelling, and the applicants have found that the polynomial for the complex aspheric mirror supports more aspheric coefficients to allow greater control over the shaping of the mirror.

With reference to Figure 5, it will be appreciated that the convex surface (32) of the diverging lensing mirror (30) or diverging lens (130) will have a defocussing effect on the light reflected by the mirror (30;129) onto the screen (18). The magnitude of this defocussing effect will depend on the radius of curvature of the mirror surface (32), and will thus vary across said surface (32).

Preferably therefore the surface (32) of the mirror (30) or diverging lens (130) will be coated with a transparent refracting material as shown in Figure 6. Light incident on the mirror (30) or lens (130) will thus be refracted by the coating (40). The degree of refraction will depend on the surface profile and refractive index of the coating for each point on the surface of the mirror (30) or lens (130). The profile of the coating may thus be pre-selected to cause refocusing of the light reflected by the mirror (30), or transmitted by the lens (130), onto the screen (18). An enlarged view of this is shown in Figure 7.

The thickness of the coating (40) may be substantially uniform across the surface (32) of the mirror (30) or lens (130), and this will produce a mild refocusing effect in use. Alternatively, the thickness of the coating may be non-uniform such that the surface profile of the coating is shaped independently of the surface configuration (32;132) of the mirror (30) or lens (130). Preferably the surface profile of the coating (40) may be calculated such that the refocussing power of the coating at each point on the surface of the mirror (30) or lens (130) substantially compensates for the defocussing of the corresponding part of the image, which defocussing is caused by the juxtaposed part of the mirror (30) or lens (130). Various

alternatives are shown in Figures 8A to 8E. In Figure 8A, no coating is used, and this Figure shows the magnifying effect of the mirror surface (32). In Figure 8B, the coating (40) has a surface (42) of greater radius of curvature than the surface (32) of the mirror (30). In Figure 8C, the thickness of the coating (40) is uniform across the surface of the mirror (30), and in Figure 8D the surface (42) of the coating (40) has a smaller radius of curvature than the surface (32) of the mirror (30). In Figure 8E, the thickness of the coating (40) is irregular.

As a further alternative, the coating (40) on the surface (32;132) of the mirror (30) or lens (130) may be formed into a plurality of contiguous lenticular lenslets (44) as shown in Figures 9A or 9B and Figure 10. The lenslets (44) may be square, rectangular or hexagonal, or any other tessalating shape. The surface profile of each lenslet (44) may be pre-selected independently of the other lenslets (44), so as to provide a refocusing power which corresponds to the strength of defocusing caused by the surface (30;132) of the mirror (30) or lens (132) adjacent the lenslet (44).

As shown in Figures 9A and 9B, the lenslets (44) may be of uniform shape and configuration. Alternatively, as shown in Figure 11, the size (and the density per unit area) of

the lenslets may vary across the surface of the lens (130) or mirror (30). In particular, it will be appreciated that where the curvature, and thus defocusing power, of the mirror (30) or lens (130) changes most greatly within unit area, there smaller lenslets (44) of varying refocusng power will be required so as to ensure that the refocusing power of each lenslet is properly matched to the defocusing action of the juxtaposed part of the mirror (30) or lens (130). Thus, in Figure 11, it will be seen that the smallest lenslets (44) are provided juxtaposed the end of the mirror (30) remote from the projection lenses (22), where the surface configuration of the mirror (30) is most convoluted. Here the defocusing power of the mirror (30) varies most with distance along the surface (32) of the mirror, and thus the refocusing power of the lenslets (44) is also required to be varied as greatly over the same area. Naturally, where the surface (32) of the mirror (30) is flatter, in this case towards the projection lenses (22), there the defocusing power of the mirror changes less dramatically across the surface (32), and thus the corrective refocusing power required also varies less with area, and so larger lenslets (44) can be employed.

In yet another alternative, the lenslets (44) may be manufactured independently from each other from any

suitable transparent, refracting material such, for example, as a synthetic plastics material, and then applied to the mirror (30) or lens (130) after manufacture.

As shown in Figure 12, a problem with the use of a lenticular coating (40) of the kind shown in Figures 9A, 9B and 10 is that light incident on one lenslet (44) juxtaposed the boundary (46) with another neighbouring lenslet (44) may be reflected by the mirror surface (32) through said neighbouring lenslet. This will cause an amount of scattering of the light reflected by the mirror. In Figure 12 the path which should be taken by the incident ray to achieve refocussing is marked "B", but the actual path taken, as a result of scattering, is marked "A".

In order to reduce the magnitude of the scattering, the thickness of the coating (40) at the boundaries (46) between contiguous lenslet (44) may be reduced to zero as shown in Figure 13. This may be achieved by laser etching after forming the coating (40) on the mirror (30).

Alternatively, the scattered light may be removed by applying a narrow non-reflecting mask (48) to the mirror surface (32) juxtaposed each boundary (40) between

neighbouring lenslets (44) as shown in Figure 14A, or by applying an optically-absorbing strip (49) to the surface (42) of the coating (40) along the boundary between each lenslet (44) and its contiguous lenslets as shown in Figure 14B.

It should be noted that the embodiments of the invention hereinbefore described may be operated with an object which is oriented normally with respect to the optical axis (28). Alternatively, the object may be inclined with respect to the optical axis (28), in which case the lenses (22) of the projection device (20) may be arranged to provide Scheimpflug Correction as shown in Figure 15, with a correspondingly inclined focal plane (24). In this case, the shape of the lensing mirror (30) or diverging lens (130) will be adjusted accordingly.

It has been found that the adoption of Scheimpflug Correction in this way may assist in correcting the distortion of the image.

The invention as hereinbefore described may provide an ultra-compact image projecting apparatus such as a rear screen projector, in which all the components of the projector can be accommodated within an area which is coterminous with the area of the screen. The optical path

length between the projection device (20) and the screen (18) is shortened by using a diverging mirror (30) or diverging lens (130) which is capable of magnifying greatly the image projected by the projection device onto the screen. The diverging mirror, or a separate diverging lens, is shaped asymmetrically to compensate for the optical distortion of the image caused by positioning the screen off-centre and inclined obliquely with respect to the mirror. The invention also provides novel forms of asymmetric diverging lensing mirror which are suitable for use in the projecting apparatus.

CLAIMS

1. An image projecting apparatus (10), particularly a rear screen projecting apparatus, comprising a projecting lensing means (20) for projecting an image of an illuminated object, a screen (18) and reflecting means (30;129) for reflecting light from the projecting lensing means onto the screen, wherein the reflecting means is positioned off-centre with respect to the screen and asymmetric diverging lensing means (30;130) are provided for magnifying further the image reflected by the reflecting means onto the screen, the lensing power of the diverging lensing means varying across the area thereof, such that for each point on the diverging lensing means, the combined focal length of the projecting lensing means and diverging lensing means is adjusted according to the length of the optical path between the projecting lensing means and the screen via that point, thereby to reduce optical distortion of the image on the screen.

2. Image projecting apparatus as claimed in claim 1 wherein said diverging lensing means is positioned at or towards a position at which the image projected by the projecting lensing means is focused, so that the light

incident on each point of the diverging lensing means corresponds to a discrete part of the image.

3. Image projecting means as claimed in claim 1 or claim 2 wherein the lensing power of the diverging lensing means at each point is pre-selected independently of the rest of the diverging lensing means so as to adjust the magnification of the corresponding part of the image, so that the image is projected substantially uniformally onto the screen.

4. Image projecting means as claimed in claim 1, claim 2 or claim 3 wherein the overall magnifying power of the diverging lensing means is such that the divergence of the beam projected by the projecting lensing means is increased by between X2 and X12 by the diverging lensing means.

5. Image projecting apparatus as claimed in any preceding claim wherein the intrinsic field of view of the beam emerging from the projecting lensing means is in the range 10 to 30°, and the intrinsic field of view of beam treated by the diverging lensing means is in the range 60 to 100°.

6. Image projecting apparatus as claimed in any

preceding claim wherein said diverging lensing means and screen are positioned with respect to one another such that the image on the screen is magnified between 2 and 20 times, typically 10 times, as compared with the size of the image which is incident on the diverging lensing means.

7. Image projecting apparatus as claimed in any preceding claim wherein said screen is oriented such that a line on the screen, which line is disposed parallel to the projection of the optical axis between the projecting lensing means and the reflecting means onto the screen, subtends an angle of between 0 and 45° to the said optical axis.

8. Image projecting apparatus as claimed in any preceding claim wherein said projecting lensing means (20) is disposed juxtaposed one end (34) of the screen (18), and the reflecting means (30;129) is disposed juxtaposed an opposing end (36) of the screen, the optical path between the projecting lensing means, the reflecting means and the one end (34) of the screen being greater than the optical path to the opposing end (36) of the screen.

9. Image projecting apparatus as claimed in any

preceding claim further comprising a housing (12), said screen occupying substantially the whole of one face (16) of the housing.

10. Image projecting apparatus as claimed in claim 9 wherein said projecting lensing means, reflecting means and diverging lensing means are accommodated within the housing (12), within an area which is coterminous with the screen.

11. Image projecting apparatus as claimed in any preceding claim wherein said reflecting means comprises a substantially planar mirror (129), and the diverging lensing means comprises an asymmetrical diverging lens (130) positioned adjacent to the mirror.

12. Image projecting apparatus as claimed in any of claims 1 to 10 wherein the reflecting means and diverging lensing means are constituted by an asymmetrical diverging lensing mirror (30).

13. Image projecting apparatus as claimed in claim 12 wherein said lensing mirror has an asymmetrical convex shape.

14. Image projecting apparatus as claimed in claim 12

or claim 13, wherein said asymmetrical diverging lensing mirror comprises a complex aspheric mirror which has a reflecting surface defined by the formula:-

$$z=\frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}}+a_2r^2+a_3r^3+a_4r^4+a_5r^5+a_6r^6+\ldots$$

wherein:- $a_2, a_3, a_4, a_5, \ldots$ are the aspheric coefficients,

k = conic constent

$r^2 = x^2 + y^2$,

z is the optical axis,

x is an axis normal to the optical axis and parallel to the screen,

y is an axis normal to the x and z axes, and

c is the bone curvature of the surface (1/base radius).

15. Image projecting apparatus as claimed in claim 12 or claim 13, wherein said asymmetrical diverging lensing mirror (30) comprises a toroidal aspheric mirror which has a reflecting surface defined by the formula:-

$$z=\frac{c_x x^2+c_y y^2}{1+\sqrt{1-(1+k_x)(c_x x)^2-(1+k_y)(c_y y)^2}}+a_4x^4+a_6x^6+a_8x^8+a_{10}x^{10}+b_4y^4+b_6y^6+b_8y^8+b_{10}y^{10}$$

wherein:- x, y and z are as defined above, and

$a_4, a_6, a_8, a_{10}, b_4, b_6, b_8$ and b_{10} are aspheric coefficients, and

c_x and c_y are the bone curvatures of the surface in the x and y axes respectively.

16. Image projecting apparatus as claimed in any preceding claim wherein said diverging lensing means comprises refocusing means for refocusing the light treated by the diverging lensing means.

17. Image projecting apparatus as claimed in claim 16 wherein said refocusing means comprises a transparent refractive coating (40) formed on the surface of the diverging lensing mirror or diverging lens, which transparent coating has a refractive index and surface profile which is controlled for refocusing the light treated by the diverging lensing means (30).

18. Image projecting apparatus as claimed in claim 17 wherein said coating (40) is formed as a plurality of contiguous lenticular lenslets (49) on the surface of the diverging lensing means.

19. Image projecting apparatus as claimed in claim 18 wherein the thickness of each lenslet (49) at its extremities (46) is minimized or reduced to zero.

20. Image projecting apparatus as claimed in claim 18 or claim 19 wherein masking means (48;49) are provided juxtaposed the boundary of each lenslet for reducing or preventing the transmission of light which passes through more than one lenslet.

21. Image projecting apparatus as claimed in claim 20 wherein said masking means comprises a non-reflecting mask (48) applied to the mirror surface, or an optically absorbing mask (49) applied to the coating surface, juxtaposed the boundary of each lenslet.

1/12

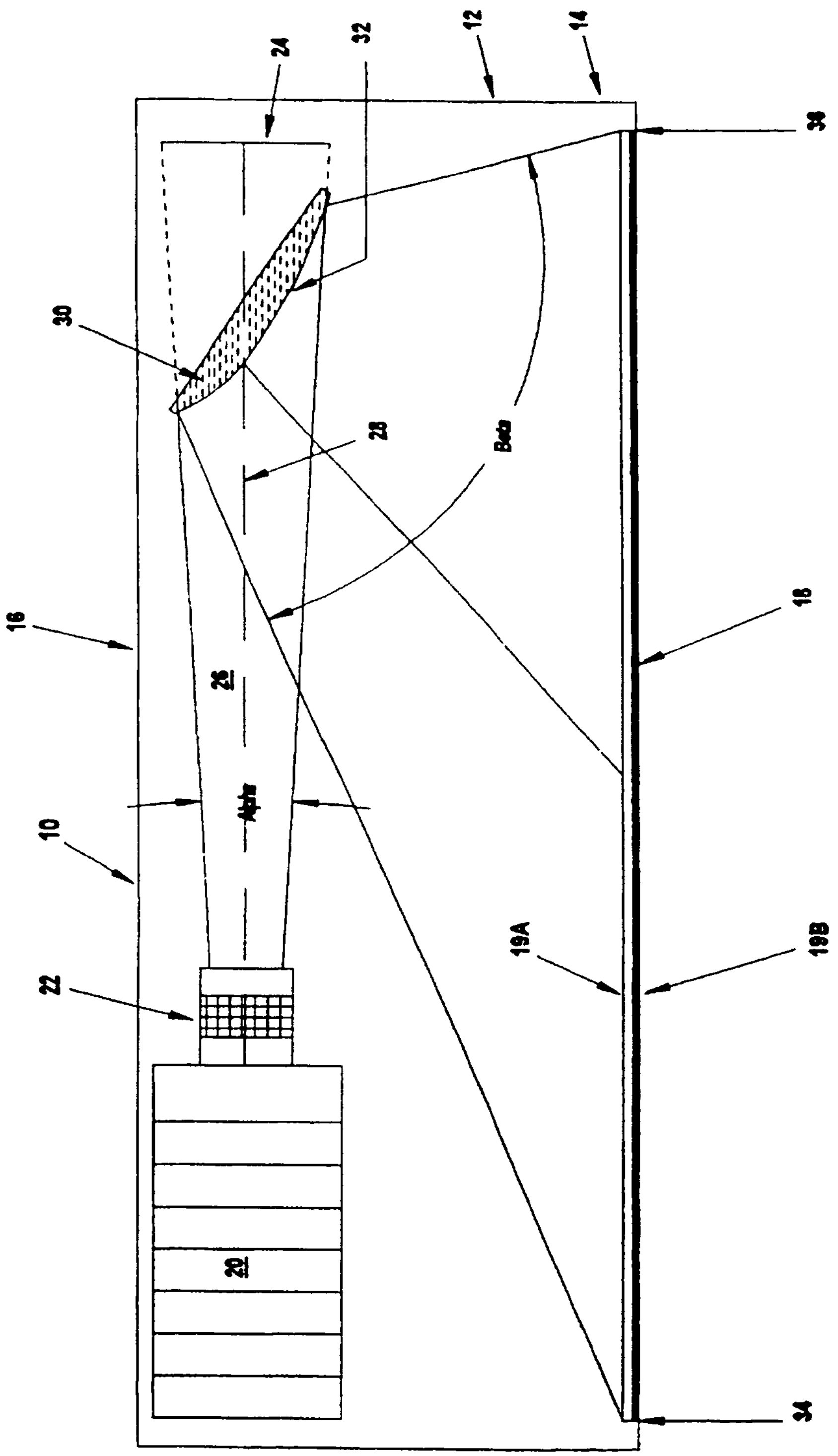


Figure 1

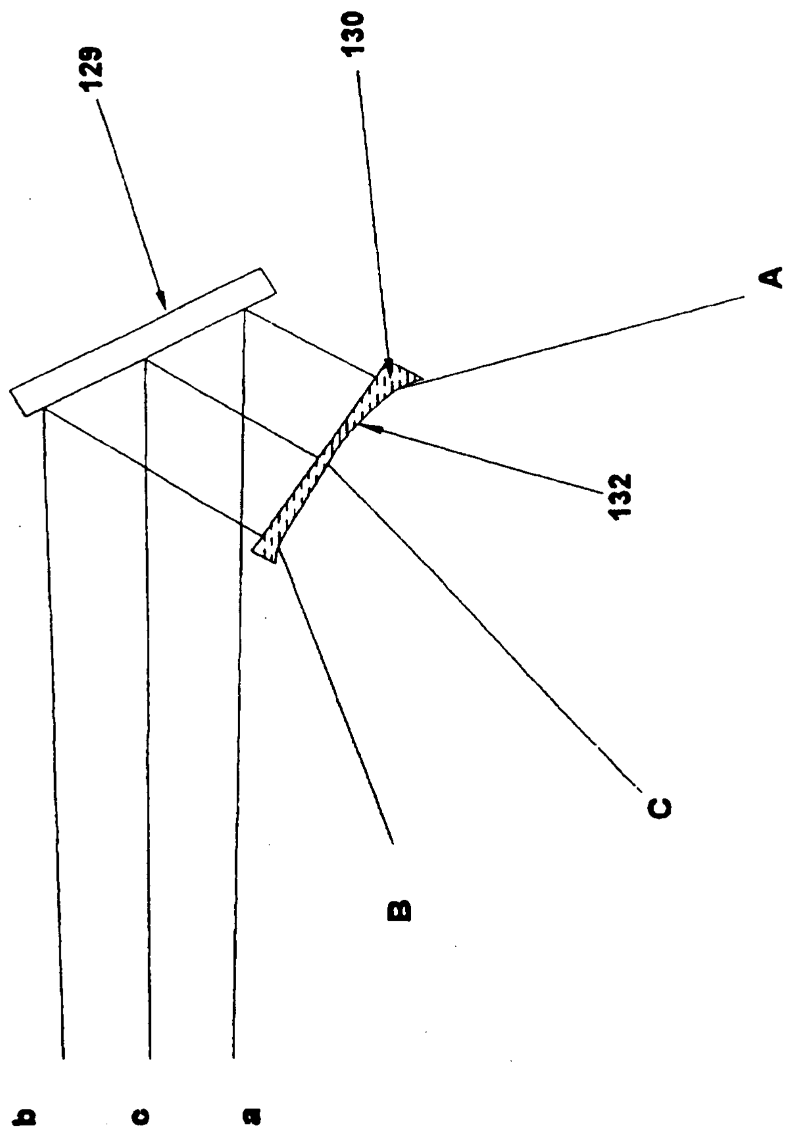
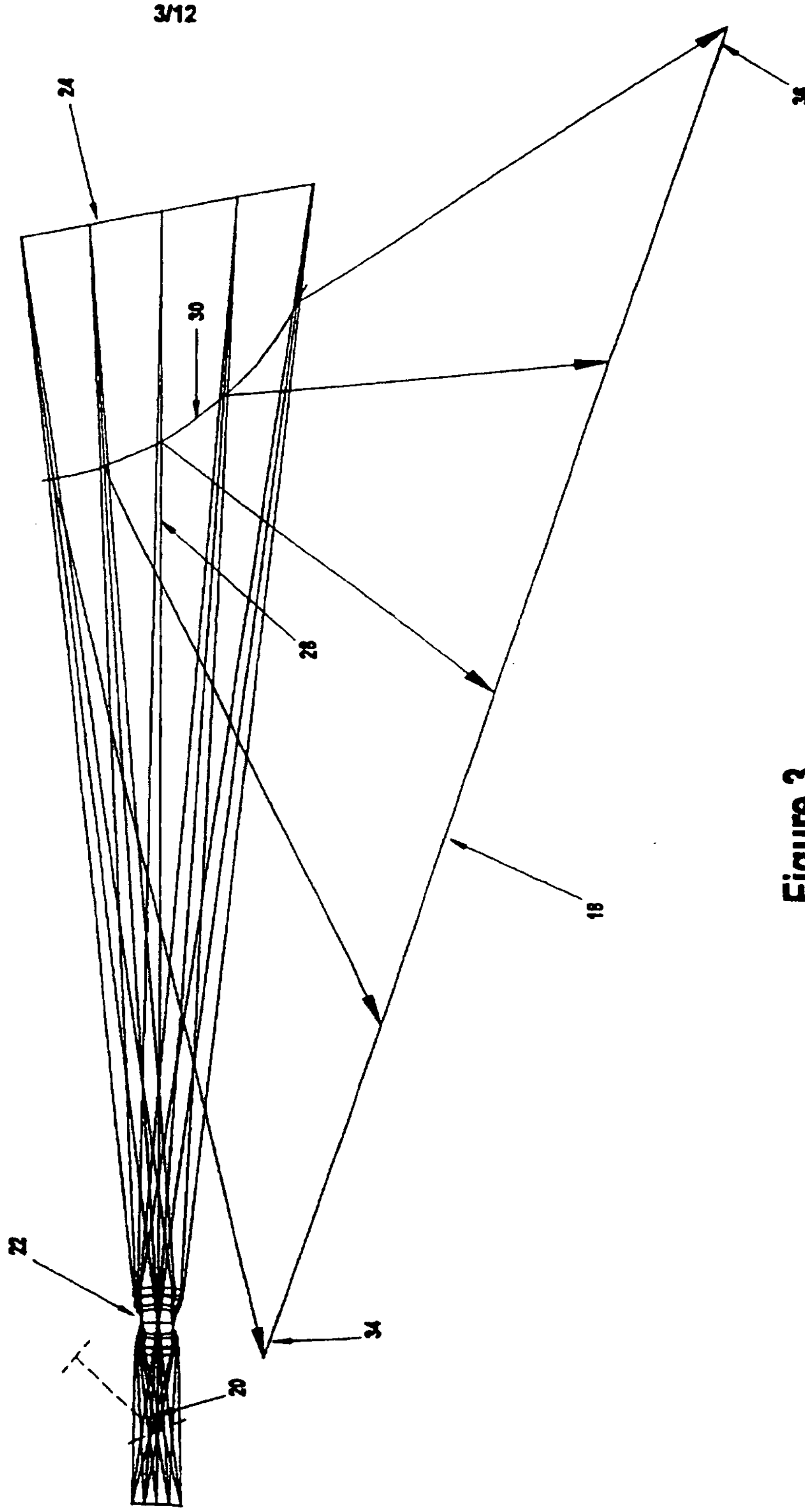


Figure 2



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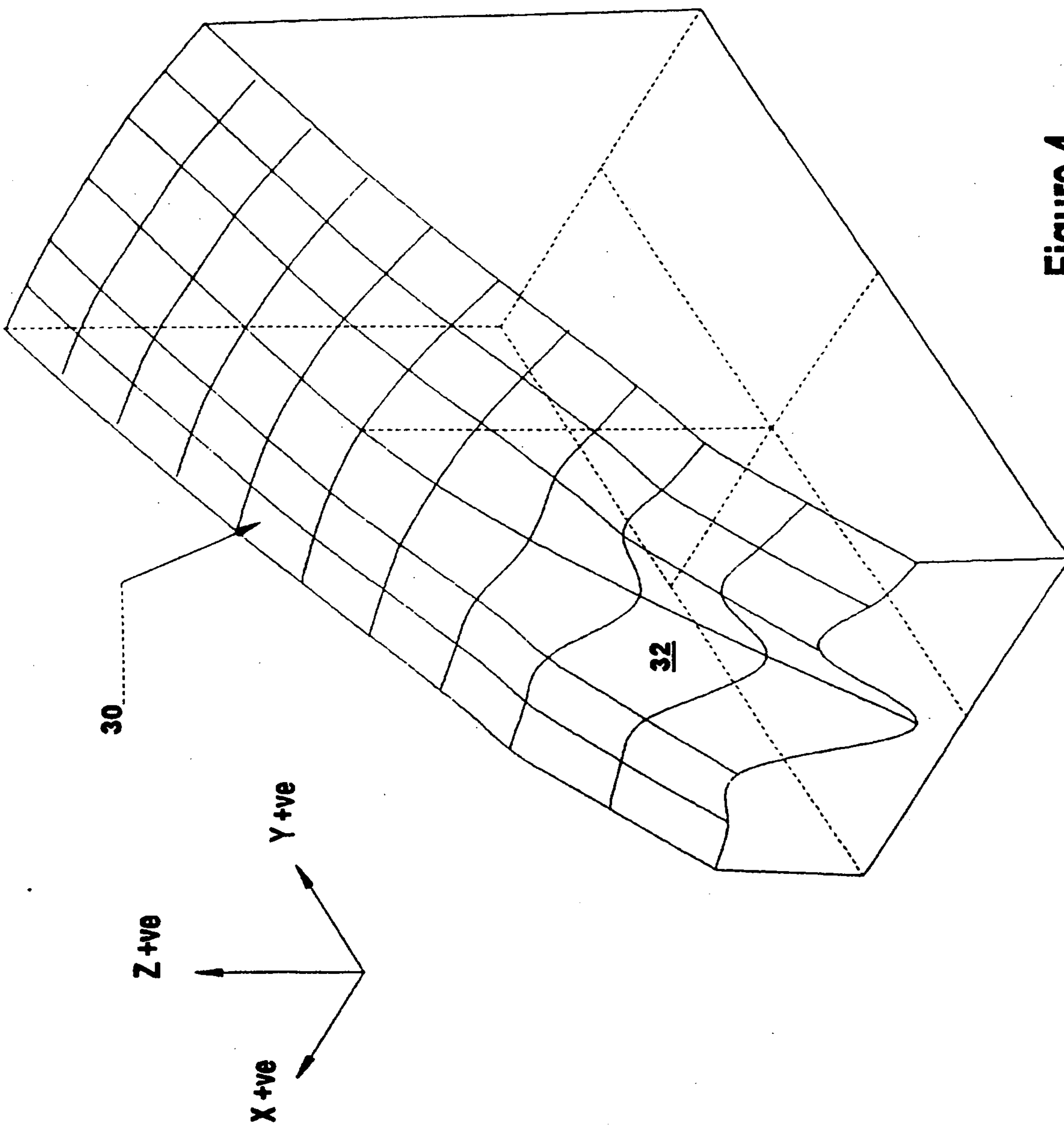


Figure 4

5/12

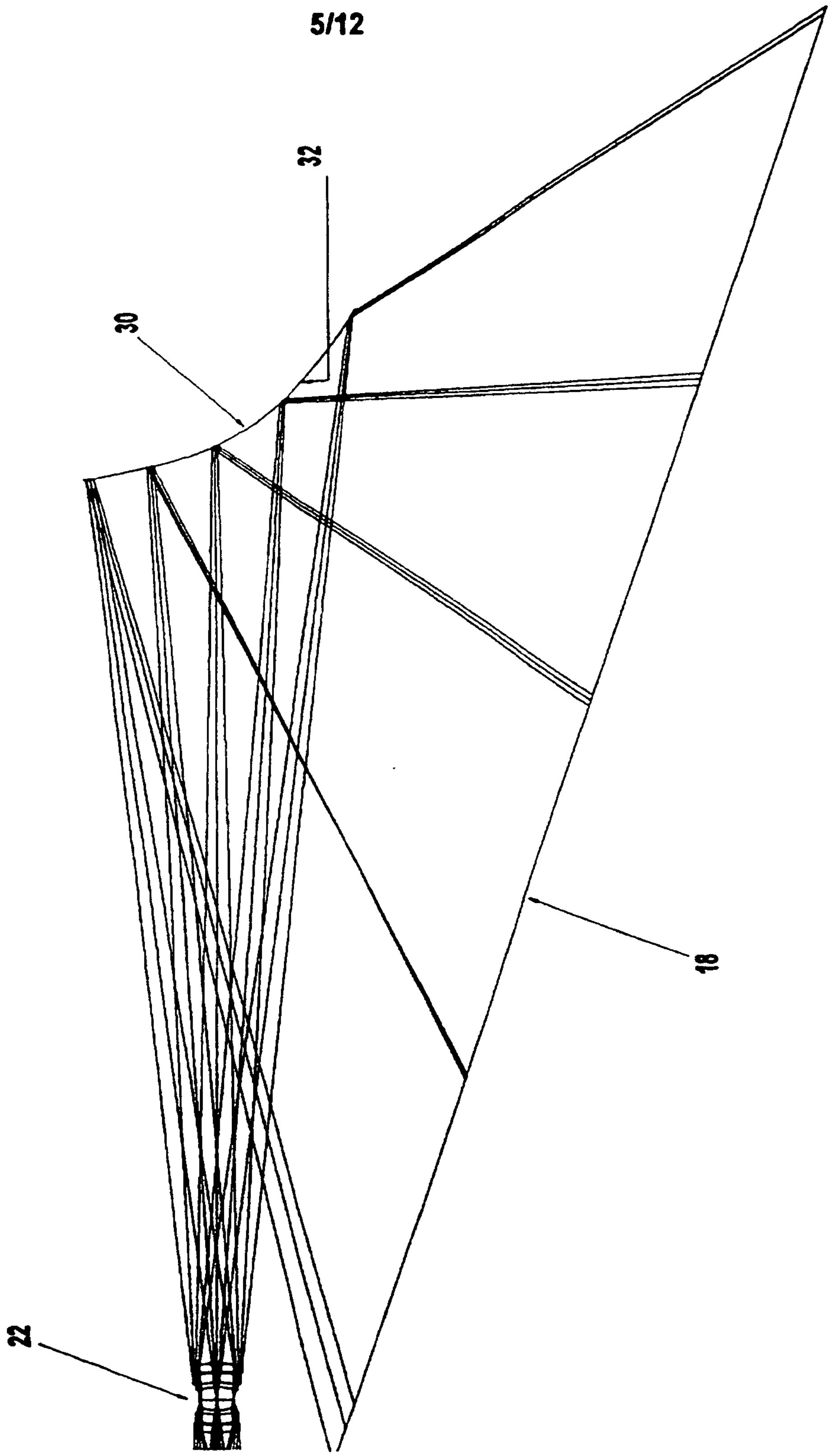


Figure 5

6/12

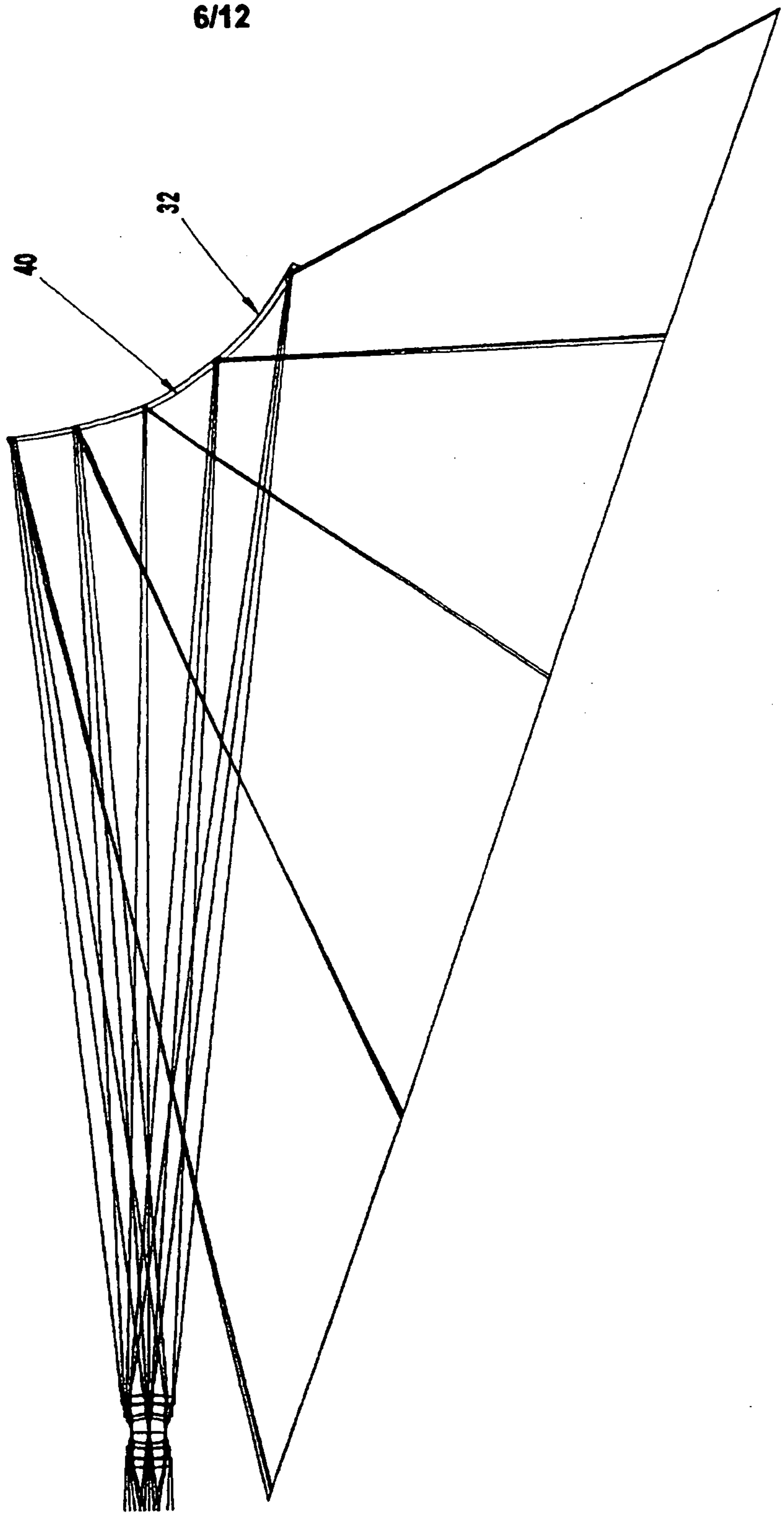


Figure 6

7/12

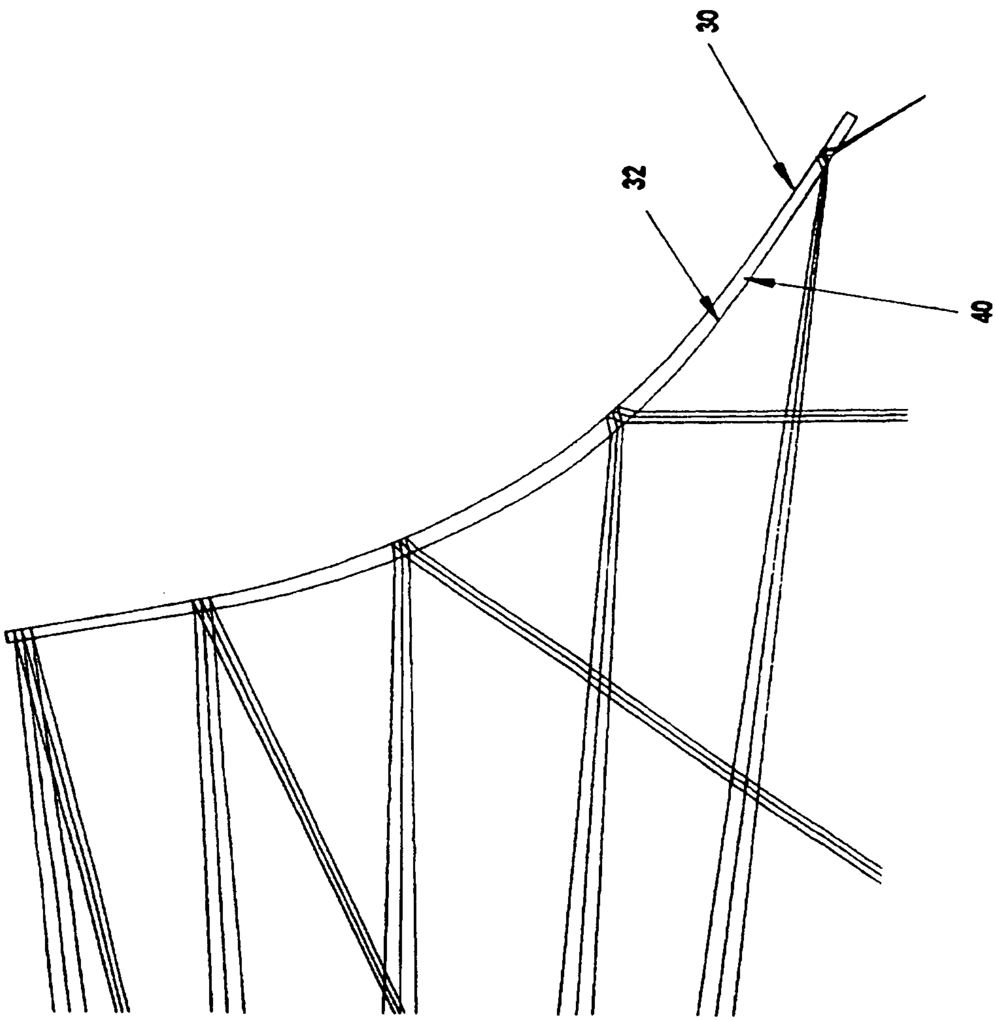


Figure 7

8/12

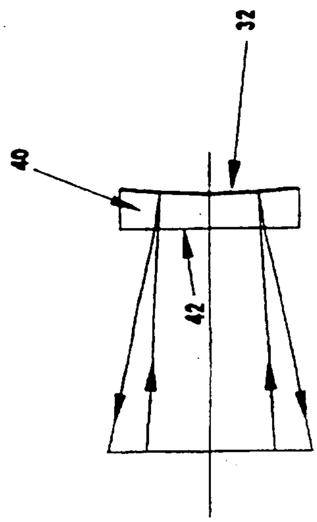


Figure 8b

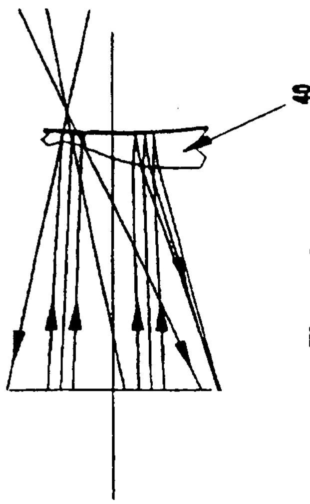


Figure 8e

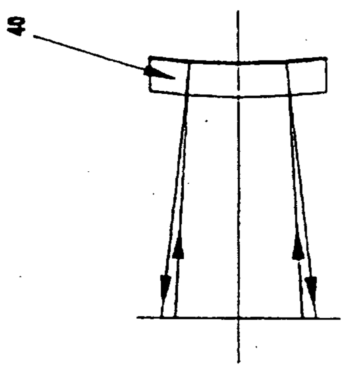


Figure 8c

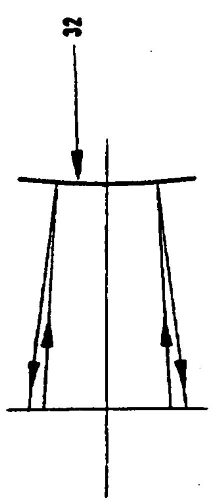
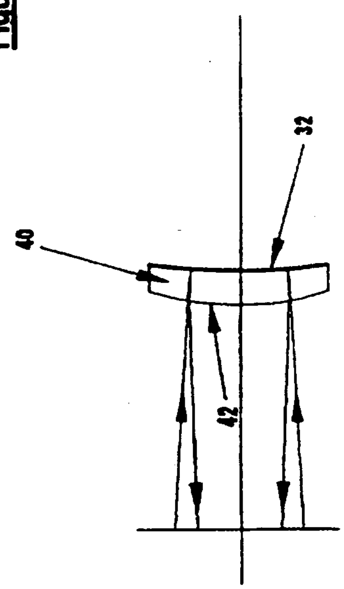


Figure 8a



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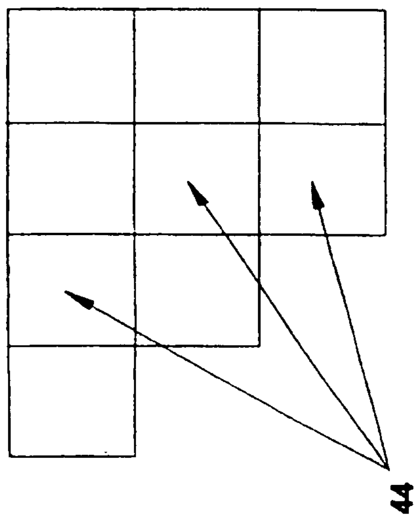


Figure 9b

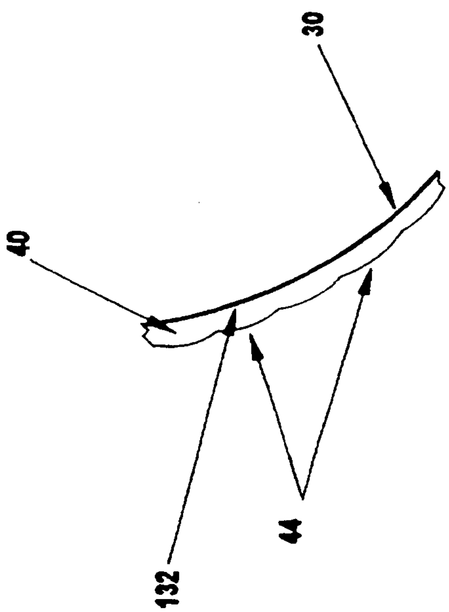


Figure 10

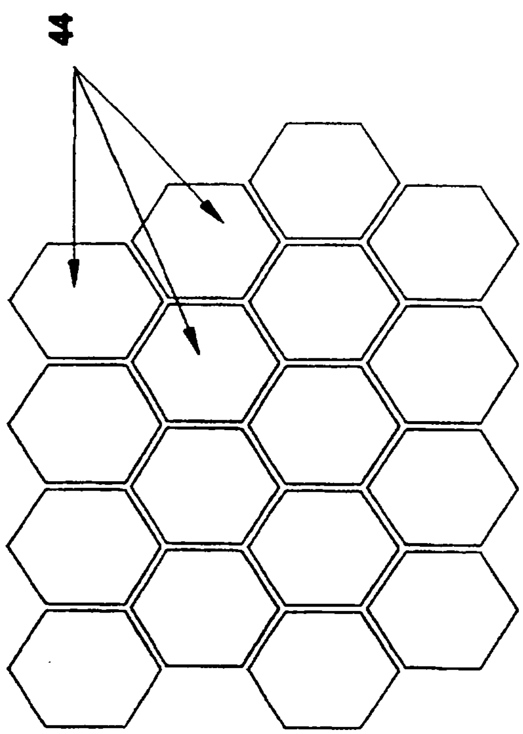
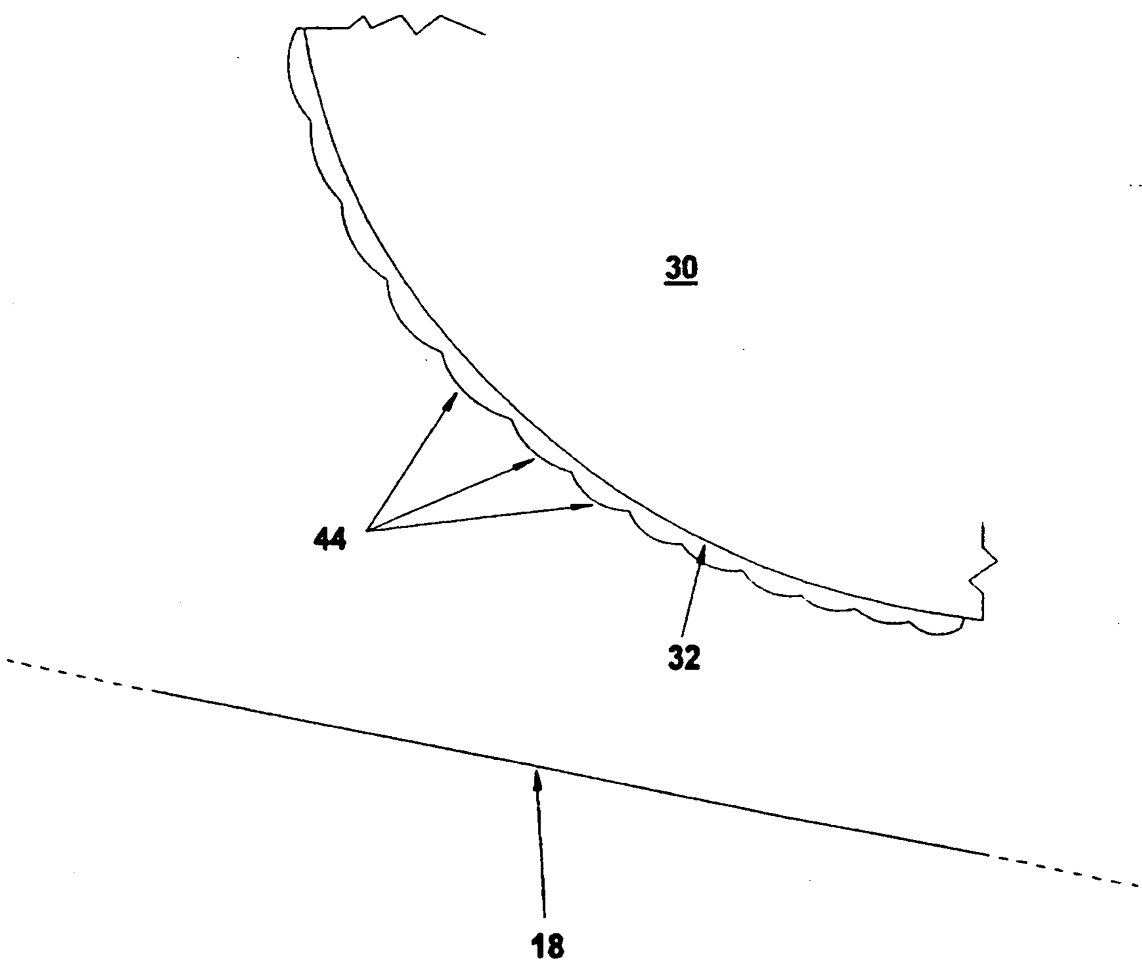


Figure 9a

Figure 11



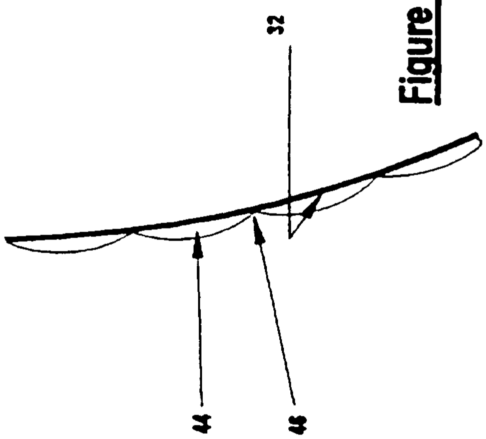


Figure 13

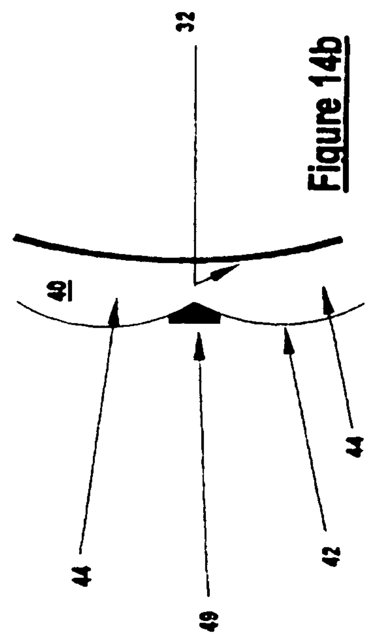


Figure 14b

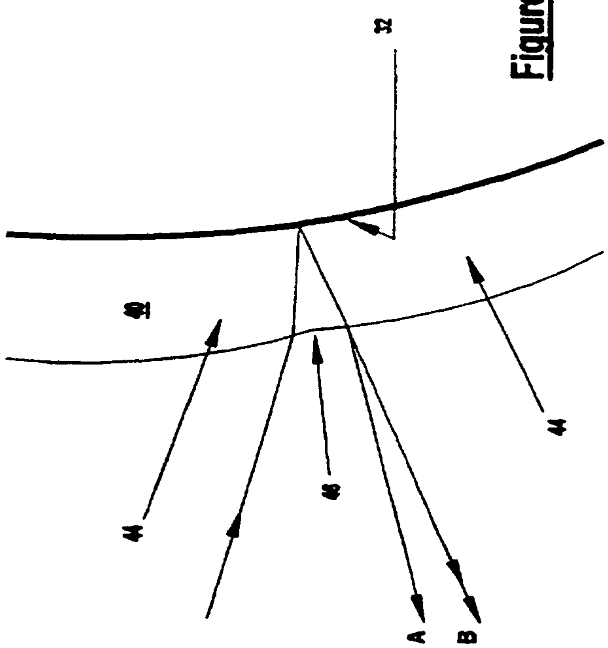


Figure 12

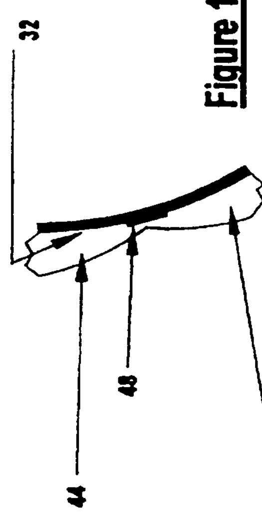


Figure 14a

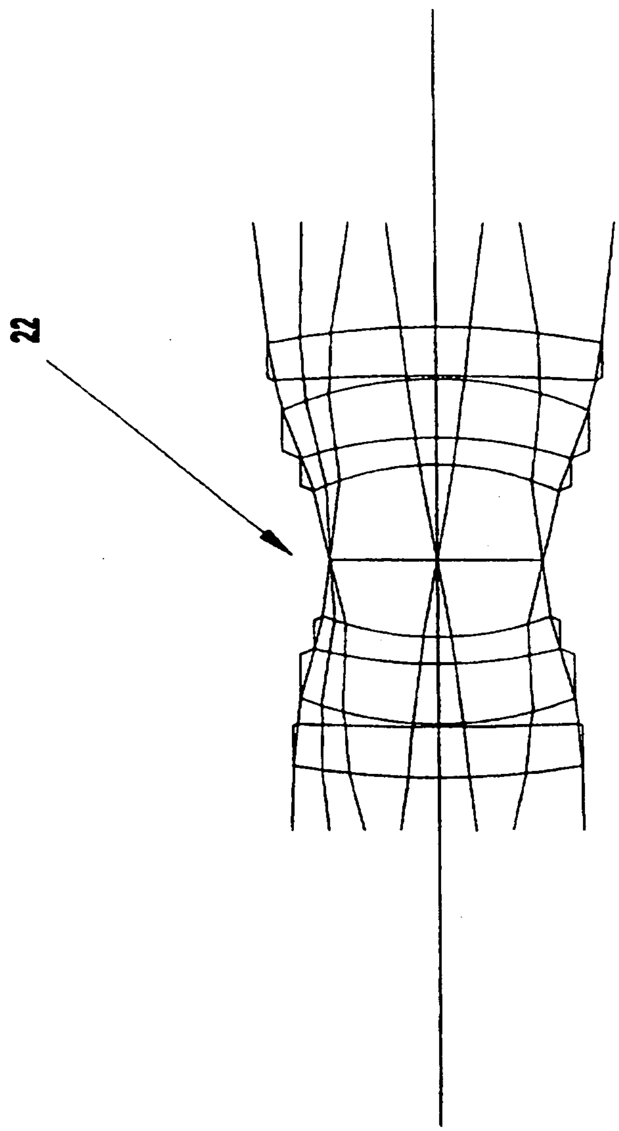


Figure 15

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/02079

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G03B21/10 G02B27/00 G02B27/18 H04N9/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G03B G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 003 080 A (MAIMAN THEODORE H ET AL) 11 January 1977 see column 7, line 40 - column 8, line 34 see abstract; figure 3	1-10,12, 13
A		11,14-21

X	EP 0 631 434 A (UNIC VIEW LTD) 28 December 1994 see column 14, line 56 - column 15, line 43; figures 19,20	1-10,12, 13

A	US 4 078 860 A (GLOBUS RONALD P ET AL) 14 March 1978 see column 2, line 49 - column 4, line 19 see abstract; figures 1-3	1,11

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
11 April 1997	22.04.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Manntz, W

INTERNATIONAL SEARCH REPORT

Int   ional Application No
PCT/GB 96/02079

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 724 199 A (NIKON) 31 July 1996 see page 8, line 13 - page 9, line 15; figures 14-16 ---	1
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 211 (P-594), 9 July 1987 & JP 62 031838 A (VICTOR CO OF JAPAN LTD), 10 February 1987, cited in the application see abstract ---	1
A	US 5 274 406 A (TEJIMA YASUYUKI ET AL) 28 December 1993 cited in the application see abstract; figures 12C,14A -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 96/02079

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4003080 A	11-01-77	DE 2624546 A FR 2313828 A JP 52014431 A	16-12-76 31-12-76 03-02-77
EP 0631434 A	28-12-94	CA 2126130 A CN 1104822 A JP 7244266 A	21-12-94 05-07-95 19-09-95
US 4078860 A	14-03-78	DE 2725444 A JP 958448 C JP 53034487 B JP 53055025 A	03-05-78 14-06-79 21-09-78 19-05-78
EP 0724199 A	31-07-96	JP 8203805 A	09-08-96
US 5274406 A	28-12-93	JP 1257834 A	13-10-89